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CUTTING A REDWOOD TREE

THE
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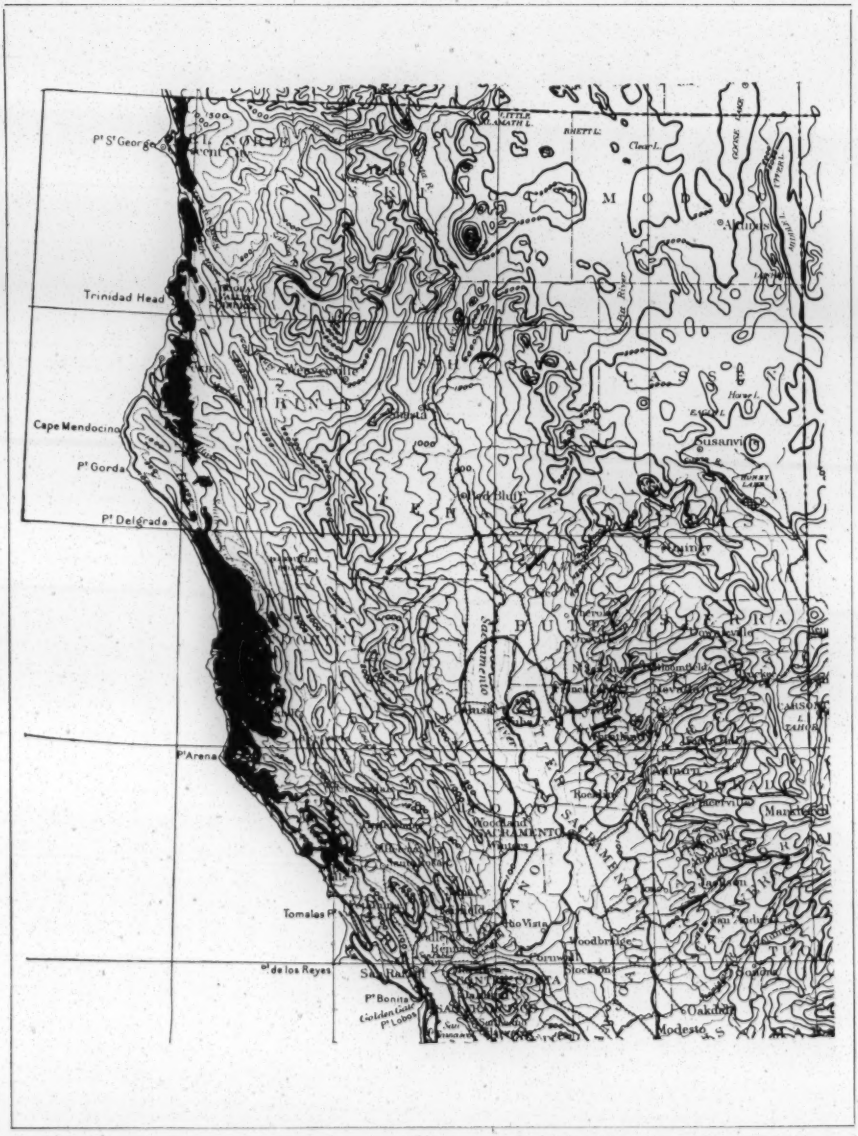
THE REDWOOD FOREST OF THE PACIFIC COAST

By HENRY GANNETT,
U. S. Geological Survey

Redwood is so called because of its color, which, when freshly cut, is a bright, though not deep, red, changing to a brown-red when thoroughly seasoned. The wood is soft, with a rather coarse, straight grain. It is easy to work, quite as much so as our eastern white pine. It contains practically no resin, but a large amount of water, which makes the green wood so exceedingly heavy that often the lower log of a tree will sink in water.

Botanically, the redwood (*Sequoia sempervirens*) is a brother of the big trees (*Sequoia gigantea*) of the Sierra Nevada, the two species being the sole living representatives of the genus *Sequoia*. It is a cousin of the cedars, which it resembles in many respects, in habit and appearance, in bark and foliage. It is an immense tree, larger than the fir of Washington, but not as large as the Big Tree of the Sierra. If often attains a height exceeding 300 feet and a butt diameter of 15 feet. It rarely branches low, but almost invariably shows a straight, fluted trunk, perfectly symmetrical, rising with a slight taper for 200 feet to the lower branches. The bark is covered with thin flakes of epidermis, lying parallel to the stem. The foliage is dull green in color, fine and drooping. It is a most beautiful tree, both in form and color.

The habitat of the redwood is peculiar. It is found only in a narrow strip, closely hugging the Pacific coast, stretching from the southern boundary of Oregon or just across the boundary—for there are perhaps 1,000 acres of redwood in Oregon—south-



MAP SHOWING THE GEOGRAPHICAL DISTRIBUTION OF REDWOOD ON THE PACIFIC COAST

Area covered by forest indicated in black

ward through northern California, nearly to the bay of San Francisco. Indeed, a few scattering groves are found south of the bay, in Santa Cruz county and other localities, and there are evidences that not many centuries ago it extended over the Coast ranges as far south as Los Angeles; but in all this region it is now practically extinct. The densest forests are found in Humboldt county. In Del Norte county, on the north, the area is comparatively small and the forests somewhat less dense; while in Mendocino county, on the south, where the redwood area is even greater than in Humboldt, the forests are not as dense, and in Sonoma county, still farther south, the timber becomes more scattering, thinning out into groves. Its habitat is a region of heavy rainfall, which comes in the winter, and of fogs which sweep in from the Pacific at all times of the year. It is a very moist, temperate region, both of which conditions appear to be essential to the growth of the species. On the north its range is probably limited by temperature, since the humidity is even greater in Oregon and Washington than in California. On the south it is probably limited by the diminishing amount of hu-

REDWOOD FOREST SCENE, ILLUSTRATING DENSITY OF GROWTH

midity. The species seems to require for its development a rather nice adjustment of temperature and moisture conditions, which are not found elsewhere, and, as will be seen later, do not at present fully meet the needs of the species, even in its present habitat.

This is probably the densest forest on earth, as measured by the amount of merchantable timber—that is, of timber suitable for the saw-mill—contained per acre. It is not the size of the trees alone which produces this, although they are exceptionally large, even in this state of large things, but it is the great number of trees on each acre, the closeness of their stand. In a redwood forest the sun never shines—it is always twilight. You are, as it were, under the roof of a vast temple, a roof of foliage, supported by great tree columns.

In order to obtain a conception of the enormous stand of timber in the redwood strip, let me commence with some familiar examples for comparison.

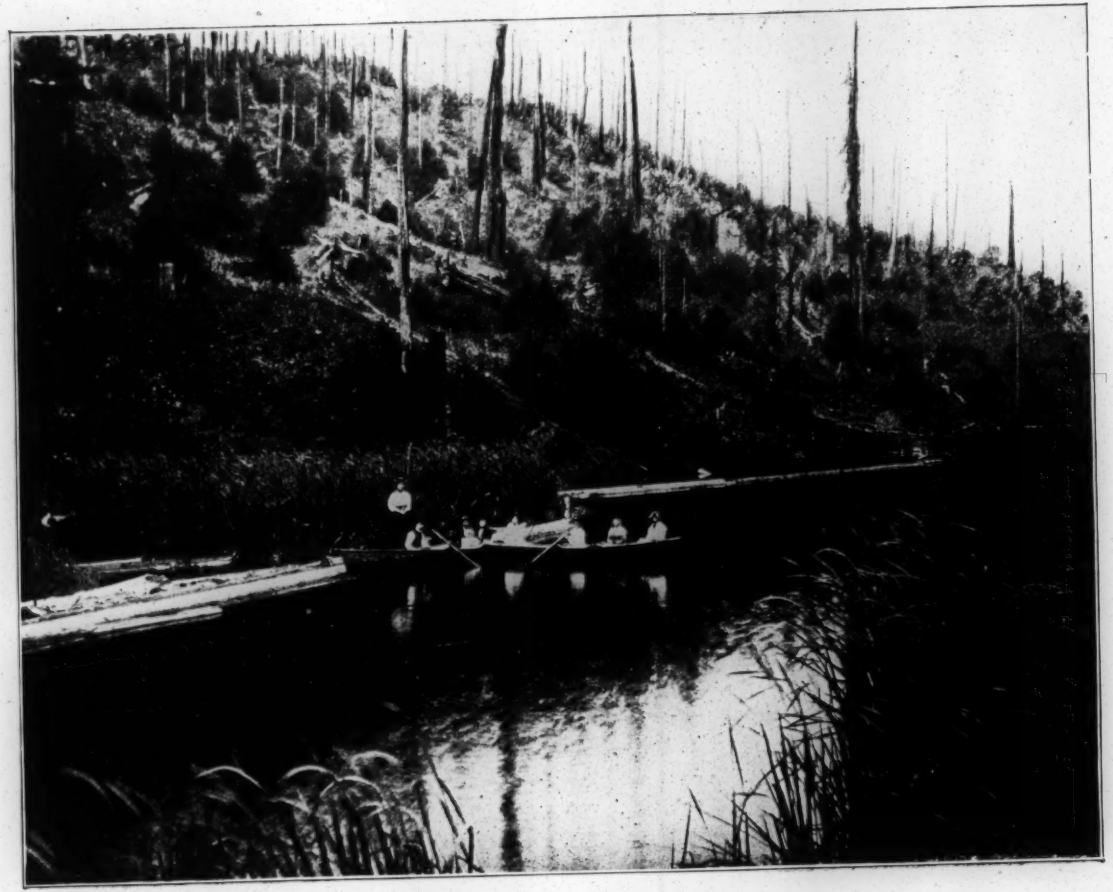
The great pineries of the southern states contain, on an average, about 5,000 feet, board measure, of standing timber per acre. Of white pine the heaviest county in Minnesota is estimated to contain an average of 5,000 feet, while others, regarded as forested, contain 1,000 to 2,000 feet; and a tract containing 10,000 feet per acre is regarded as heavily forested. Contrast these figures with the following: The average stand of redwood upon 173,000 acres in Mendocino county is 44,000 feet per acre. There is here nearly nine times as much timber on an acre as in the southern pineries; yet even this is exceeded in Humboldt county. Upon 96,443 acres in this county the average stand is 84,000 feet per acre, nearly seventeen times as great as in the southern states. The lumber companies around Eureka, California, the principal center of the redwood industry, have realized, since they commenced operations, an average of between 75,000 and 100,000 feet per acre, and one of these companies has for ten years cut an average of 84,000 feet per acre of redwood alone, besides fir and spruce, which would increase the amount to nearly 100,000 feet. These last figures are not in any way estimates, but the actual products of the mills. The disproportion is even greater than appears here, for the standard for lumber used in the redwood country is much higher than in the east, and consequently the estimates of the amount of timber are correspondingly less. For instance, whereas in the east logs

eight inches in diameter are cut and sent to the mill, and knotty stuff is sawed, on the Pacific coast nothing less than 16 inches in diameter is sawed, and clear lumber only. If the redwood were used as economically as the southern pine, these estimates of its stand might easily be 50 per cent greater. The forests of Washington and Oregon are very heavy, but they by no means equal the redwoods in density. The most heavily forested county in Washington, Skagit, contains an average on its forest land of but 28,000 feet per acre, and in Oregon the stand is no greater. Of course, there are in these states individual acres, and even square miles, which are vastly more heavily forested; but so, also, are there in the redwood strip. On Mad river, near Eureka, a lumber company is at work in a tract of several square miles which actually cuts 150,000 feet per acre.

There is on record a single acre, near Garberville, which yielded in the mill 1,431,530 feet in lumber. There was sufficient lumber on this acre to have covered it with a solid block of frame dwellings ten stories high. A redwood tree of average size, say five feet in diameter at the butt, furnishes enough lumber to build an ordinary cottage, and many trees have been cut each of which would suffice for half a dozen such houses. One tree is on record as having scaled 66,500 feet. A tree was felled in a lumber camp near Eureka in 1898 which was 16 feet in diameter inside the bark, and which scaled over 100,000 feet, and there is standing in the same neighborhood a tree 22 feet in diameter which scales nearly twice as much. Such examples of wonderful yield might be multiplied to any extent, but this would merely involve repetition.

The redwood strip is composed of the westernmost of the Coast ranges, with the valleys between them. It is narrow at the north, in Del Norte county, where it is not over five to six miles in breadth. It widens in Humboldt county to an average of 10 to 12 miles; then south of Eel river, in the southern part of the county, its continuity is broken for a few miles. At the north edge of Mendocino county it commences again, and in the central part of that county attains it greatest breadth, of perhaps 20 miles. Farther south, especially in Sonoma county, the redwoods scatter, being found in detached clumps and groves, which become more and more scattering southward. The trees, however, remain as large as elsewhere.

The closest and finest growth is in Humboldt county, near the northern end. That portion in Mendocino and Sonoma counties



SPROUTED REDWOOD ON CUT AREAS

is not as heavy or continuous, nor are the trees as valuable for lumber, as they branch lower down. The wood is, however, of slower growth, is denser and harder, and perhaps more durable. The best lumber and the heaviest growth is everywhere in the valleys and on the flats. On the hillsides the trees are smaller and not so close. Nowhere is there any young growth. The youngest trees, which are found only in the northern portion of the belt, are several hundred years of age.

When the timber has been cut there is no sign of reproduction from seed. In many localities sprouts are growing from stumps in the cut areas, but even this form of reproduction is limited. Indeed, everything appears to indicate that for some reason, probably a progressive drying of the climate, the present environment is not favorable to the growth of redwood, and that with the clearing away of the present forests the end of the species as a source of lumber will be at hand.

The area of the redwood belt has been carefully mapped, and is, as nearly as can be estimated, 2,000 square miles, or 1,280,000 acres. The stand of timber on this area is not so easy to ascertain. The figures given above in this article are the best that have been obtained. I will recapitulate them with additions. In Del Norte county, out of 67,000 acres of redwood land, 11,000 acres are estimated to contain an average stand of 60,000 feet. In Humboldt county, out of an area of 500,000 acres, 96,443 acres have an average stand of 84,000 feet, with a range in different tracts from 25,000 to 200,000 feet. These figures are corroborated by the result of all the cutting done in the neighborhood of Eureka, where nearly all the lumbering of the county is done. The companies report an average yield of between 75,000 and 100,000 feet per acre. In Mendocino county, out of a redwood area of 640,000 acres, 173,000 acres are reported to contain an average of 44,000 feet, with a range from 12,000 to 75,000 feet. In Sonoma county the timber is so scattering that the total amount, which is spread over an area of some 75,000 acres, is comparatively slight.

Using the above figures, we obtain as the amount of standing redwood the following:

	Feet
Del Norte county	4,000,000,000
Humboldt county,	42,000,000,000
Mendocino county	28,160,000,000
Sonoma county, say	1,000,000,000
	75,160,000,000

To appreciate the magnitude of these figures, it may be said that the annual cut of lumber in all the mills of the United States is about one-third of this amount. The redwood strip alone would therefore supply the entire country with mill timber for three years.

Many estimates of the amount of standing redwood have been made, with results widely at variance with one another. The area of the belt has long been pretty well known, and the discrepancies among the estimates seem to be due mainly to differences in the estimated stand per acre. The first estimate that I find was made in 1881 by John Dolbeer, of Eureka, who gave 23,650 million feet. At about the same time Mr E. L. Allen, secretary of the Redwood Manufacturers' Association of San Francisco, made the estimate published in the report of the tenth census, which was 25,825 millions. In 1885 Mr Hubert Vischer published, in the report of the California State Board of Forestry, an estimate of 30,500 millions, and in 1890 Capt. A. C. Tibbetts, secretary of the Humboldt Lumber Manufacturers' Association of Eureka, estimated it at 97,500 million feet.

The area seems to be generally agreed upon as being from 1,000,000 to 1,280,000 acres. The measurements from the best map available, that of the State Board of Forestry, give the latter figures. It is out of the question that the redwood lands yield, on an average, so little as 20,000 to 30,000 feet per acre. All estimates of stand and all records of cut show yields far in excess of these figures; and it cannot be contended successfully that these estimates and records relate only to selected areas far above the average. There is, as yet, very little selection of timber lands taking place. The whole territory is so heavily forested that it is no advantage to select those most thickly clothed with timber, but rather a disadvantage. The only selection yet made has been on the score of accessibility by stream in earlier times and by rail route at present. I consider, therefore, that the figures quoted above, which represent 280,000 acres out of 1,280,000, or nearly one-fourth of the entire area, together with the records of the entire amount cut in Humboldt county, furnish a fair sample of the stand in the belt. Captain Tibbetts' estimate seems to me, under present logging conditions, much too high, but I have no reasonable doubt that his amount will eventually be cut from the belt, owing to the economies to be effected in the future.

The annual cut by the mills, excluding other uses to which the wood is put, such as firewood, shingles, ties, posts, and poles—

TYPICAL REDWOOD FOREST SCENE

for such uses are not considered in the estimate of the stand—is 250,000,000 feet. At the present rate of cutting, therefore, the supply will probably last for three hundred years.

The rate of cutting will, however, increase and, as transportation is cheapened, may increase many hundred per cent. For instance, the completion of an isthmian canal will open up the entire market of the eastern states, where redwood will inevitably replace white pine, causing an immense demand. On the other hand, with the increased demand will come increased economy in the utilization of the wood. At present only about one-third of the tree emerges from the mill as sawn lumber. Nothing but clear lumber is sawed. One may go through miles of lumber yards at Eureka and examine millions of feet of lumber without finding a knot or, indeed, an imperfection of any kind. The upper branched third of the tree is left in the woods.

In felling the tree there is much damage done. Although great care and skill are exercised, the fall of one of these giants, weighing scores of tons, not infrequently splinters them; occasionally, too, a tree falls across its fallen fellows and thus produces great destruction.

In the mill the amount of lumber is diminished, first, by the slabs cut from the outside of the log, and, second, by the sawdust. This last is an item of great importance, especially where circular saws are used. The great saws used in the first cutting of the logs make a cut five-eighths of an inch in thickness. This means that if the log were cut directly into inch boards, more than one-third of the wood would be converted into sawdust; but this is not often done. The log is commonly first cut into thick planks and beams, and these are subsequently cut into smaller dimensions by smaller, thinner saws. Moreover, in most of the great mills today the first cutting is done by band saws, which are much thinner, and consequently convert less of the log into sawdust.

There is one cause of destruction from which this tree is entirely exempt—that is, fire. Containing no pitch, but, on the other hand, a large amount of water, it will not burn when green. No fire can run in a redwood forest. We shall, beyond reasonable question, have the use of our supply of redwood; shall not have the pain of seeing it go up in smoke. It is the only one of our coniferous lumber trees which is thus exempt.

The redwood is entirely in private hands, having long ago passed from government ownership. It is mainly held in small

tracts by a great number of persons, but a few of the lumber companies have large holdings. Classifying the 280,000 acres above spoken of by holdings, it appears that—

Of a quarter section, 160 acres or less, there were	6	holdings
From ¼ section to a section (640 acres)	7	"
From 1 section to 4 sections	8	"
From 4 sections to 18 sections	11	"
From 18 sections to a township	7	"
Over a township	3	"

The last were tracts of 30,000, 30,000, and 27,000 acres. The above are the holdings of lumber and mill companies. Whether this classification properly represents the character of the holdings of the entire belt is doubtful. It is probable that the holdings of those not owners of mills or logging camps are smaller.

The forest is nearly pure redwood. Occasionally spruce and Oregon pine—that is, red fir—are found, forming perhaps 10 per cent of the forest only. The southern part of the strip is, on the whole, composed of older trees than the northern part, and the wood is denser and of less rapid growth. In the north are some tracts covered with trees not more than 200 or 300 years old, while the age of the mature trees reaches several hundred, perhaps a thousand years. The annual rings show that in the north, especially in damp valleys, the growth is several times as rapid as in the southern part of the strip.

The methods used in logging are, in the main, similar to those employed in the great fir forests of Washington, but with slight modifications to fit different conditions. The use of animals, such as oxen and mules, for dragging the logs from the woods is over; so are the days for driving logs in streams. More modern methods are universally employed. Indeed, the most modern methods of labor saving are here in use. In every respect a redwood logging camp and a redwood lumber mill are thoroughly up to date—nay, more, they are the pioneers in labor-saving devices. The trees are felled in this wise: They are chopped half-way through on the side on which they are to fall, and then the other half is cut with the saw. Two days' work of two men is required to fell a tree five feet in diameter. The felling must be done with the utmost accuracy, as the trees stand so thickly that when felled they cover the ground completely, and yet they must not be allowed to fall on one another, as that would involve great loss by breakage.

The felling is done in the winter, the season of rains, when the ground is soft, and the trees are left lying on the ground until late spring, when things have become drier, when the whole thing is set on fire. This fire burns the brush and branches and much of the bark, but does not injure the trees themselves, which are still too wet to burn. Then the work of cutting up the trees and getting the logs out begins. The trees are sawed by hand, with whipsaws, into logs, generally 16 feet in length, although greater lengths are not infrequently cut for special needs. The big logs are split into halves and quarters for convenience in handling and sawing. From the end of the railroad, for railroads have taken the place of streams in the transportation of logs, a road is built to the logged area. This may be merely a dirt road, of hard, compact clay, kept wet and muddy by liberal applications of water, packed in bags on horses, or it may be a skid road, paved with small logs, laid crosswise at short intervals, and likewise kept slippery. A force of 50 to 75 men is employed, and two donkey engines. The latter do all the work, taking the place of oxen and mules, and to a great extent of men, in the labor of moving logs about in the woods and dragging them down to the railroad.

The donkey engine in the woods is anchored by wire cables to stumps, at a strategic point, so that in subsequent operations it will move the log and not itself. Then a wire cable, attached to a drum on the engine, is carried through pulleys to the log to be moved, and is attached by hooks, so that by winding up the cable on the drum the log is moved to the desired position. Often much ingenuity is required for the proper placing of pulleys in order to produce the desired result, but in all cases the machine, directed by experienced heads, does its work quickly and effectively. It is extremely interesting to watch the varied operations of a donkey engine in handling the logs and clearing away the waste lumber and not the least interesting part of it is the quickness and clear comprehension of the men. There is no fuss or noise; everything in the varied operations goes on quietly and smoothly. If the foreman gives instructions they are general ones, and in detail each man knows his part, recognizes what he has to do, and when to do it. Soon a train of logs, 10 to 12 in number, is on the road chained together tandem; then the cable-donkey is called upon. This is a stationary engine, located at the end of the railroad. From its drum goes a wire cable along the road up to the slashings, just like the cable

HAULING LOGS BY CABLE

of a street-car line, except that the cable is on the surface instead of below it. This cable is fastened to the leading log of the train, the engine is started, and the train moves railroadward. Just in advance of the train walks a man with a bucket with which he dips water from tubs along the road and wets the track. Arrived at the end of the railroad, a third engine is put to use in loading the logs on the railroad trucks by the use of wire cables. Here the logs are scaled and measurements re-

A TRAIN LOAD OF LOGS

corded. When the train is loaded it is hauled down to the mill and the logs dumped into the water, there to lie until their turn comes for conversion into lumber.

The work in the woods is hard. Although every device is used to reduce manual labor, there remains sufficient to make this one of the most wearing of physical occupations, and it is said that few men can stand the strain for any great period. The work is also extremely dirty, owing to the burning, so that the men look like stokers. Naturally, this work commands high pay, and with high pay a superior class of men, both physically and mentally, are obtained. I took dinner one day in a camp

with about 75 men, all splendid specimens of manhood and all black as negroes—faces, hands, and clothing—from the charcoal in which they work, but well read, intelligent, and interested in the doings of the outside world.

The mills of the redwood strip are as progressive and up to date as are the logging operations. The logs and the lumber are moved and handled everywhere by machinery in the most complete and ingenious manner. They are drawn from the pond up into the mills and are rolled on to the carriage and moved into place for the saw by ingenious devices operated by steam. The logs are sawed by band saws—a continuous band of steel, with teeth cut on one edge, running over drums above and below. This is preferable to the circular saw for two reasons: it can saw a log of almost any size, which the buzz saw or any combination of buzz saws cannot do; and, second, since it can be made much thinner than the buzz saw, there is less waste of wood in sawdust. In some mills the band saws have teeth cut on each edge, so that a cut may be made both as the log moves forward and backward. The boards, beams, joists, plank, etc., as they come from the band saw, are distributed by rollers, steam-worked, to the proper parts of the mill for future cutting, while the slabs and other waste are similarly carried off to waste-heaps. The lumber, as it comes from the band saw, is edged, cut to smaller dimensions, etc., by small circular saws, in some cases harnessed in gangs, so that several cuts are made at once. To watch the wheels go round in one of these big mills is a most entrancing occupation.

Redwood is in almost universal use on the California coast. In the construction of houses little other timber is used, even as far south as Los Angeles and San Diego. It is exported as far south as Valparaiso, Chili, and westward to Japan and Australia. Indeed, considering its cheapness, $14 per thousand feet in Eureka for the best, it seems strange that it has not found its way in quantity to the Atlantic coast. Certain it is that before many years redwood will supplant the now vanishing white pine in eastern markets.

IS CLIMATIC ARIDITY IMPENDING ON THE PACIFIC SLOPE? THE TESTIMONY OF THE FOREST

By J. B. Leiberg

The extension of explorations and observations in the region of country west of the Rocky mountains tends in many ways to develop and confirm the proposition that a steadily progressive aridity is slowly replacing former more humid climatic conditions. This change is manifest in various ways—most conspicuously in the decreasing volume of water in many of the lakes and streams throughout the region, as shown by the existence of former beach lines at higher levels, and in the profound disturbances and modifications taking place in the native flora. The phenomena which follow the advance of aridity are not limited by altitude; for, while the desert conditions at low elevations exhibit them in their most intense aspect, they are also clearly traceable to the highest summits, where gradually dwindling glaciers and abnormally high extensions of certain lowland types of forest show the general trend of the climatic change.

In the general exhibition of increasing aridity there are to be noted two important distinctions. One is dependent upon climatic effects, the other upon the relief of a region as affecting the drainage, and is termed soil aridity. Excellent examples of the latter occur on the plains of the Columbia, where the great coulées or sunken water channels, which traverse the plains in all directions, are separated by comparatively narrow blocks of plateau-like country. The drainage from these elevated tracts is extremely rapid. As a consequence, their summits and slopes are left without sufficient soil moisture during the growing season to maintain a forest stand, although the annual precipitation is high enough to make tree growth possible, were the drainage conditions different. Similar examples occur in the forested subhumid and humid regions, where any large area on which temperature and precipitation are practically the same throughout often shows a growth of species belonging to the drier areas in the midst of the humid groups of trees, merely because the angle of slope in some localities favors a more rapid drainage than upon the contiguous areas. Similar effects are sometimes

produced by excessive porosity of soil. Loose sand and gravel or volcanic ashes are poor conservators of moisture, and part with it readily, both through evaporation and percolation. Soils of these sorts are not common, however, in these regions, where, as a rule, moisture-retentive qualities are the predominant characteristics. In the following discussion the question of soil aridity is eliminated and the effects of climatic aridity alone are considered.

The variations of plant life which accompany the encroachments of aridity are diverse and often very complex. Innumerable general modifications and adaptations occur, mostly tending toward a more or less successful resistance to the stress imposed by drier climatic conditions. Local peculiarities, depending on adjacent heights or depressions, specialize—that is to say, they lessen or increase the general degree of aridity prevalent over any large area, thereby favoring minute adaptations or gradual transitions to more extensive and pronounced modifications.

In the region west of the Rocky mountains, the forest as a unit is the type of vegetation which, aside from the purely aquatic element of the flora, suffers a more profound disturbance of its equilibrium and is more quickly and thoroughly driven out by the advancing aridity than any other. In the herbaceous and to a lesser extent in the suffrutescent flora there is a gradual evolution of new forms, or of entire groups of certain types, to meet the changing environments. It is doubtless true that many herbaceous and shrubby species have gone under in this struggle within recent geologic times, while others are so rare and scattered as to warrant the assumption that they, too, are rapidly approaching extinction; but, on the other hand, there are many groups possessing the power of adaptation in a high degree, and through the slow development of modifications or by evolution of what we term species, they are enabled for a time to withstand successfully very adverse conditions.

It is different with the forest growth in this region. Overwhelmingly composed of cone-bearing trees, representing comparatively few species, it has an extremely narrow margin for the evolution of new forms or species. The fact stands out clear and distinct that most of the types and species of the order of coniferæ west of the Rocky mountains possess the power of adaptation only in a very limited degree. Their outlying forms are few and only vaguely definable. It is true that we can recog-

nize differences such as that of texture and color of wood, variations in bark characteristics, or in the general port of the various individuals of a species upon any given area, but the differences are not such as to indicate that they constitute a definite and sharply determined trend in adaptability. They rather convey the impression that they are a series of expiring gasps of a type of vegetation which reached its culminating point of development immensely far back in time, and is now on the road toward complete extinction.

The forest areas in this region which have been more closely examined than any other in relation to the effects of increasing aridity are the tracts adjacent to and encircling the Columbia watershed in Idaho, eastern Oregon, and eastern Washington. We shall first examine the tracts lying within these limits, thence passing to others elsewhere, not so well known.

When the coniferous flora of the region is investigated it is found that certain species have a far higher ratio of endurance to conditions of aridity than have others. This might be taken to indicate a certain degree of adaptability, but the strongly marked characters which separate the species were acquired ages ago, and, with the exception of one or two species, do not in our region in the present age show any marked evolutionary tendencies.

The minor effects of the encroachment of aridity upon the forested areas are many, but comparatively unimportant.

The greater effects are contained in one general phase, which strikes at the very foundation of the species' existence. It consists in a gradual loss of reproductive power in the individual trees, and hence in the species as a unit, and is marked by two periods. In the first we have a gradual crowding back to more humid tracts of such species as require a considerable degree of soil and atmospheric moisture for their growth. They are replaced by others capable of enduring subhumid or distinctly semi-arid environments. In the second period we have a gradual crowding out or a complete extinction of the species of replacement, hastened or caused in the latter, as in the former, case by a loss of reproductive vigor, and a final complete deforestation of the particular area and the creation of a treeless region.

There are three general types of climatic conditions to which the term arid will apply. They are semi-arid, arid, and desert. As here employed, the semi-arid are regions not necessarily deforested, but which support a tree growth of peculiar species in

other localities than in proximity to streams and lakes; the arid are regions completely deforested, away from streams and lakes, natural or artificial, but which bear an often rich and varied flora of herbaceous and suffrutescent vegetation; the desert are tracts without vegetation. The two former are abundantly represented in this region by very large areas, as we shall see. The third, or the desert, does not exist here. It is common to speak of "the desert regions of eastern Oregon," for example, but the fact is that in no place has aridity reached its third and last stage. When herbaceous vegetation is absent, as on certain alkali flats east of Steins mountains, or on drifting sand-dunes along the Columbia and on the plains of eastern Washington and northeastern Oregon, it is due to local soil conditions, not to absence of sufficient precipitation.

To facilitate a more detailed examination of the various forest conditions, as modified by increasing aridity, the region under consideration will be divided into certain classes or zones. These zonal distinctions have reference solely to the amount of precipitation which each class receives without regard to altitudinal limitations, and will be designated arid, semi-arid, subhumid, and humid areas.

THE REGIONS OF ARIDITY

The regions of greatest aridity north of the 42d parallel of latitude between the Rocky mountains and the Cascades are found: in Idaho, on the Snake River plains; in eastern Oregon, on the plateau areas between the Snake and the Owyhee rivers on the one hand and the Steins mountains on the other; in the region bounded by Crooked river and Malheur lakes and river on the north, Steins mountains on the east and the northern boundary of Nevada on the south, and in the Deschutes depression between the Blue mountains and the Cascades; in eastern Washington, north of the Snake and east and south of the Columbia river.

The aridity which prevails upon these areas is of various degrees of intensity, depending more or less upon local conditions and the proximity or distance of humid, snowy mountain ranges. In eastern Washington the driest section is situated at the eastern base of the Cascades, and extends eastward some 60 or 70 miles, gradually merging into uniform semi-arid and subhumid conditions as the moisture-condensing Bitter Root ranges are approached. In eastern Oregon the most arid tracts are found

to the west of the Owyhee, extending in a westerly and northerly direction 100 to 120 miles. In eastern Washington the Cascade range evidently contributes largely to the aridity which exists on its east slope, and is therefore a local factor; but in eastern Oregon the most arid tracts lie at a distance of 200 miles or more east from the Cascades, and owe their origin to the interception of the moisture-laden westerly and southwesterly winds by the Sierra Nevada, and in a lesser degree by other intermediate ranges. Irrespective of local conditions, however, it can be stated as a general proposition, borne out by observed facts, that the crest of the advancing wave of aridity in the intermontane region of southern Idaho, eastern Oregon, and eastern Washington is traveling from the southeast toward the north and northwest. The tracts termed arid bear no forests. It is true that narrow fringes of trees skirt many of the rivers or creeks which meander through these areas, but the growth is made possible only by the humid or subhumid soil conditions due to proximity of streams, and cease at short distances from their banks.

Looking backward in time, there are abundant proofs that many of the now treeless tracts once bore a forest covering. Silicified wood is found in thousands of localities in the region where no tree growth is now possible, owing to insufficient precipitation, and its occurrence on the surface of these plains, not as transported material, but in place, argues in favor of the hypothesis that the extinction of this forest growth does not date back so very many centuries. The fossil wood, where it occurs on the treeless areas, is found resting directly on the volcanic rocks, indicating that sufficient time has not passed since the forest grew there to change the surface in any perceptible degree. The fossil woods referred to consist of remains of oak and probably of pines and junipers, and if not wholly identical with species that now exist in the adjacent regions are very closely related. There are also many localities on these arid tracts where are found fossil plants of Tertiary age imbedded in rock, deeply covered with basalt, but they belong to a period when specifically distinct climatic conditions, as compared with those of our age, prevailed in the region, and are not here considered. The areas classed as arid exist in many localities in this intermontane region. The most extensive have already been noticed; but, favored by local conditions, many small lobes from the main body of aridity stretch out on all sides. That they should penetrate

into the areas we term semi-arid is to be expected, as they are but a step removed, but it is rather surprising to find them in the midst of subhumid conditions; yet such is exactly the case. Along the eastern base of the Cascades many of the south and east-facing slopes are distinctly arid, though surrounded by and adjoining decidedly subhumid regions. Similar conditions are encountered on the east, south, and west slopes of the Powder River mountains, on the plateau areas between the Clearwater and the Salmon rivers, in Idaho, and even in scattered localities north of the Snake, among the terminations of the western spurs of the Bitter Roots. Crossing the Bitter Roots and entering the basins and plateaus on the west slope of the main range of the Rocky mountains, we once more meet these extensions of arid conditions projecting into the subhumid regions. They are very well marked in the region of the Blackfoot basins, where they cross the main range and connect with the arid upper Missouri plains through the comparatively low passes at the head of the Blackfoot tributaries; thence stretching westward, they cover large areas of the Clark fork of the Columbia basin, and following the valley of this stream approach to within 60 or 70 miles of the eastern Washington plains. In the Clark fork watershed these arid extensions are usually bordered by a margin of semi-aridity—their penumbra, as it were—but in many places they join and exist in the midst of the subhumid timbered tracts without any semi-arid transitions. The causes which operate to bring about these apparently erratic and sporadic advances of arid conditions are not very clear. Where they occur in proximity to the general body of aridity their presence is easily explained, but we find such tracts covered with herbaceous and shrubby vegetation peculiar to very arid regions in the midst of a forest of yellow pine, or even higher, where the elevation borders on the subalpine. These isolated spots might be compared to sparks wafted far in advance of a coming conflagration, each one constituting a nucleus for the further spread of its own peculiar conditions.

The altitude of the arid tracts varies considerably. At the junction of Snake and Columbia rivers it amounts to less than 150 feet above sea-level. On the southeastern Oregon plateau it rises to fully 6,000 feet on the slopes of various ranges, such as Steins mountains, the ranges to the east of Warner lake, and on unnamed heights between the Paulinas and Malheur lake. Farther north we find the arid tracts at elevations varying from

600 feet to 3,000 feet on the eastern Washington plains and from 4,000 feet to 5,000 feet in the regions between the Bitter Roots and the main crest of the Rocky mountains.

THE REGIONS OF SEMI-ARIDITY

From the arid regions we enter those termed semi-arid. We meet here a forest growth. It is one which throughout these regions is strictly typical of semi-arid environments. As it comes most closely in contact with the highest degree of aridity and has to bear the full force of the ultimate and permanent deforesting processes, its condition and aspect become doubly interesting. This forest growth is wholly composed of junipers belonging to the following species:

Juniperus monosperma, One-seeded juniper.
Juniperus occidentalis, Western juniper.
Juniperus scopulorum, Mountain juniper.

They occur in the various semi-arid districts as follows: Western juniper, in eastern Oregon and probably on the Snake River plains; mountain juniper, on the areas between the Rocky and Bitter Root mountains, thence extending into the eastern Washington plains; one-seeded juniper, on the Snake River plains and along the hills bordering this river valley nearly to its confluence with the Clearwater.

The western juniper is the most abundant of these species and forms true forests. It occurs as close and absolutely pure stands in many localities. The most extensive are found in Crook and Wasco counties, in Oregon, where it covers areas of over 100 square miles, with a stand twice as heavy as the ordinary stand of yellow pine in Oregon and Washington. Outside of these large tracts the species occurs in small groves or aggregates, or as scattered individuals, throughout most of the plains region of eastern Oregon. These juniper forests exhibit clearly the second period of the general phase of progressive extinction, that of deficient reproductive capacity.

The western juniper reaches large dimensions on the eastern Oregon plains. Individuals occur with basal diameters up to six feet. It is a species of slow growth, centuries being required to produce such large trees as just noted. In examining the stand, one is struck by the great preponderance of old trees, the comparatively small percentage of young, and the marked deficiency of seedling or sapling growth. It is noticeable that the older trees produce enormous quantities of galbuls—juniper berries—

but on examination one finds that most of them contain only aborted seeds. Round about the trees the ground is thickly strewn with berries, but the lack of seedlings proves how few of the seeds possess germinating power and indicates that the general climatic conditions are not favorable to seed germination. In many localities extensive burns are found. They have ravaged the edges of the forests or plowed wide swaths through what once were very dense and uniform stands. Some of these burns are very old, the stumps indicating that perhaps a century or more has passed since the fires. Others are comparatively recent. Reforestation does not take place on the burned-over areas. They become a part of the adjacent, arid, treeless tracts. Places occur in the midst of heavy stands entirely devoid of trees and stumps. It is probable that they represent extremely ancient burns, showing that reforestation in the juniper growth has practically ceased on areas contiguous to the main body of aridity. It is not alone when fire has swept the juniper forest out of existence that one notices a lack of reforestation. It is also to be seen adjacent to settlements where the growth has been cut clean for domestic uses, and the great number of detached groves and scattered individuals dispersed over the plains are arguments in the same general line. It is, of course, impossible to say with absolute certainty that all these outlying groups are parts of a uniform juniper forest, which once extended over the entire plains regions of eastern Oregon, yet from analogy we are justified in concluding that such is the fact. The fires and direct human agencies which are cutting into the larger bodies of forest at the present time produce just such detached groves and scattered individuals, and the gaps give every promise of remaining permanently deforested.

The forest of western juniper extends up to the subhumid areas, where it meets the western yellow pine. It even goes beyond a strict line of demarcation and penetrates several miles into the yellow-pine areas. It has been noticed that in many places the juniper produces an abundance of fully developed seeds and a plentiful supply of seedlings where it comes in contact with the subhumid regions. Such would be a natural result of the more favorable moisture conditions prevalent there.

Accompanying the front of the semi-arid wave, comes a tree which, in these regions, can endure neither the same high degree of aridity as the juniper nor so great a humidity as the yellow pine. This is the mountain mahogany, *Cercocarpus ledifolius*,

which therefore furnishes an excellent indication of the limits of the *quasi* semi-arid and lower subhumid conditions which mark the front of the semi-arid advance and the rear of the subhumid retreat. The mountain mahogany occurs, therefore, in numerous localities all along the edge of this debatable ground and mingles not alone with the yellow pine, but in many instances also with the lodgepole pine, ascending to elevations of 7,000 feet.

Crossing from the eastern Oregon plains to those of the Snake, in southern Idaho, we find a growth of the one-seeded juniper, *Juniperus monosperma*. Comparatively little is known of the growth and distribution of the junipers on the Snake River plains, but this species is one which prevails largely on the arid regions in Utah, and should, perhaps, be regarded as being pushed toward the north through the stress of increasing aridity farther south. Coming into the interior Rocky Mountain region, we meet a juniper much resembling the Virginian juniper or red cedar of the east. It is the species named mountain juniper, *Juniperus scopulorum*, a small tree or shrub. It occupies more or less closely the semi-arid regions on the west slope of the range, doubtless extending across to the eastern declivities along the lines of semi-aridity. This juniper can endure a greater degree of humidity than the other two species mentioned. So far as it has come under my observation, it reproduces itself freely. It has not yet encountered a stress of arid conditions excessive enough to lower its seed-producing capacity beyond the balance point. It extends along various of the mountain streams into the plains of eastern Washington, usually keeping close to the streams. It does not spread into the open plateau region of this state to any noticeable extent, indicating that the semi-aridity of the interior Rocky Mountain basins, where the tree grows on hillsides and in valleys alike, is not so intensive as on the open plains of eastern Washington.

THE SUBHUMID REGIONS

Adjoining the region of semi-aridity lie the subhumid belts. Four species of conifers are of common occurrence here. They are: Western yellow pine, *Pinus ponderosa;* red fir, *Pseudotsuga mucronata;* lodgepole pine, *Pinus murrayana*, and great silver fir, *Abies grandis*. Their endurance of dry soil and climatic conditions is in the order named, the yellow pine ranking highest and the great silver fir lowest in the scale.

The western yellow pine occurs generally throughout the entire subhumid area in this region. In course of time it has succeeded in establishing a high degree of adaptability to the desiccating climatic changes, and it therefore forms the extreme rear of the coniferous growth in the subhumid belt, receiving the full force of the oncoming semi-aridity. While the tree thus shows its drought-resisting power, it is erroneous to suppose that it has reached a stage of adaptation where it absolutely requires dry regions for its development. The heaviest stands of western yellow pine that have come under my notice, varying from 30,000 to 50,000 feet B. M. per acre, occur in small patches in the Selway basin of the Bitter Root forest reserve, where the precipitation probably is not less than 70 or 80 inches per annum. Where the species is found under such conditions, it is fair to assume that it represents the more ancient form, capable of enduring more humid environments than the forms which now make up the bulk of the species in these regions. As a rule, however, the tree occupies the lower areas of the subhumid regions, and is mostly of open or scattered growth.

Coming now to the effects of semi-aridity upon the growth of this species, we may observe that as a rule it has not progressed far enough to seriously affect its reproductive capacity over any very large area. We find, however, where the species borders the semi-arid tracts of greatest intensity or where here and there long narrow tongues, lobes, or thin lines of it project several miles from the main body of growth into them, that in such localities the reproductive capacity of the tree is exceedingly limited or altogether wanting. In other places, especially in eastern Oregon, where a few small groves or single trees are found crowning some isolated eminence entirely cut off from all direct connection with the species elsewhere, the same condition is noticeable; and, precisely as is the case with the western juniper, the ovules are generally unfertilized, or, if fertilized, most of them abort, and those that are fertile and develop into perfect seeds fail to germinate. In consequence, seedlings are rare or altogether lacking in such localities. One of the phenomena noticeable in this species, when much exposed to the desiccating influences proceeding from contiguous arid tracts, is a remarkable dwindling in its cone dimensions. Normally, in these regions, the mature cones are from three to four inches in length; but where the species occurs in proximity to the deforested areas on the eastern Oregon plains, the cones are frequently not more

than one and a half to two inches in length. A most conspicuous example of this phenomenon are the yellow-pine forests on the northern slopes of the Paulina mountains, where thousands of individuals bear cones but a trifle longer than those of the lodgepole pine, and the cone dimensions of the entire growth are far below the normal. As this tract of forest is separated only by a narrow strip of semi-aridity from areas of intense aridity, it is naturally under a high stress of the latter condition of climate, and the inference is fully warranted that the decrease in cone dimensions is a forerunner to general sterility in the species upon these particular areas.

Going farther northward there are seen thousands of localities throughout the yellow-pine areas which are absolutely deforested or contain a few, very old, lone individuals. Some of these tracts consist of south-facing hillsides, which receive the full force of the desiccating rays of the sun. If they, in addition, possess a high angle of slope, causing too rapid drainage, soil aridity is likely to result, with consequent deforestation. But many bare tracts exist when soil aridity is not a factor, and the influence which prevents the spread of the adjacent forest into such areas must be climatic, so far as can be determined.

The middle and upper portions of the subhumid belts carry, in addition to the yellow pine, the other species enumerated. Two of them exhibit clear traces of yielding to the effects of semi-aridity. They are the great silver fir and the red fir. The former is exceedingly deficient in cone production, but yields a high percentage of seeds with germinating power; the latter is a free cone producer, but matures an insignificant proportion of its ovules. In this respect it acts exactly similarly to the western juniper. The great silver fir possesses small powers of adaptability. On the western spurs of the Bitter Roots it has developed a type of tree low, small in diameter, soft and sappy in its wood, short-lived, and with extremely scanty cone production. This form takes a lower place in the subhumid zone—that is to say, nearer to the line of semi-aridity—than does the larger and more fruitful type. The adaptability of the red fir is of a much higher type than the foregoing. Notwithstanding its deficient seed production, there is no evidence that it is not maintaining the integrity of its stands throughout our region. It is not confined to subhumid areas exclusively, thriving and developing its largest dimensions in extremely humid situations on the west slope

of the Cascades; but in the region under consideration it belongs to the subhumid areas, and, as before remarked, it is here deficient in seed production. A factor enters here to be considered later. This is temperature conditions. It is evident that unless a certain ratio of increase in the mean annual temperature accompanies the aridity, there is a limit of tolerance beyond which certain species cannot be forced. When this limit is reached the species must succumb, and this is probably the reason why the red fir does not push far into the humid areas in these regions.

The lodgepole pine possesses the highest power of adaptability among the subhumid group of trees. It ranges from the humid down through the subhumid and well into the lower edge of the semi-arid belts. While not a plentiful producer of perfected seeds, most of the ovules aborting, it amply makes up for this deficiency by its multitude of cones and the early age at which it begins to produce them. If the present vigor of the species continues, it promises to become the dominant one on all subhumid and humid areas in our region. In the subhumid forests of eastern Oregon, along the lower slopes of the Cascades, three species enter which are lacking farther north. They are:

Abies concolor, White fir;
Libocedrus decurrens, Incense cedar;
Pinus lambertiana, Sugar pine.

The white fir, perhaps not specifically distinct from the great silver fir, occupies the same general place in the subhumid group of trees on the more southern areas that the latter does on the northern. We might even suppose that the great silver fir is a modification of the white fir evolved to meet changing temperature and humidity conditions. It is evident from the relative position which the white fir occupies that its limits of endurance to increased temperatures and lower humidity are far higher than those of the great silver fir.

The incense cedar and sugar pine come into the middle areas of the subhumid belts. Their distribution or retreat northward, or into the humid areas, is limited by temperature considerations. As they show no adaptability to meet them, their extension northward is precluded and their extinction will be rapid, compared with other species in this region. The sugar pine is a free cone and seed producer, while the incense cedar appears to be deficient in this respect.

THE HUMID REGIONS

From the subhumid tracts we come to the humid ones. These are chiefly limited to the mountain regions. When they extend into the plains or into areas of lower humidity, they do so only in the bottoms or on the northern slopes of deep canyons or the northern slopes of ridges. On the other hand, it is everywhere noticeable that the subhumid areas send long, strong lobes and extensions into the humid tracts, carrying their characteristic trees with them and indicating the coming ascendancy of drier climatic conditions.

The trees which compose the forests in this zone group themselves into three divisions, according to their altitudinal range. The first group, occupying the higher elevations, contains the following species:

Larix lyallii, Lyall larch;
Pinus albicaulis, White-bark pine;
Tsuga pattonii, Mountain hemlock.

The second group contains species which most generally occupy areas at the lowest elevations in the zone. They are:

Thuja plicata, Pacific arbor-vitæ;
Larix occidentalis, Western larch;
Tsuga mertensiana, Western hemlock;
Pinus monticola, Mountain white pine.

The third group contains species which range indiscriminately from the upper to the lower areas of the humid zone and are as follows:

Abies lasiocarpa, Alpine fir;
Picea engelmanni, Engelmann spruce;
Pinus murrayana, Lodgepole pine.

Of the species included in this group, the Alpine fir possesses the least power of adaptability, the lodgepole pine the highest.

In addition to the species enumerated, there are the following whose behavior as to altitudinal extensions and limitations are not very thoroughly known. They are:

Libocedrus decurrens, Incense cedar;
Chamæcyparis nootkatensis, Yellow cedar;
Abies amabilis, Amabilis fir;
Abies nobilis, Noble fir;
Abies shastensis, Shasta fir;
Pinus flexilis, Limber pine;
Pinus lambertiana, Sugar pine.

With the exception of the limber pine, most of these species are, in these regions, confined to the Cascades, and do not extend very far from the high, upper slopes of the range. Only the sugar pine and incense cedar come into contact with regions of subhumidity.

I have already noted that strong and broad projections from the subhumid areas push far into the humid belts. This is most marked along deeply eroded valleys, where high summer temperatures prevail. Not only do the subhumid conditions become conspicuous in the humid belts along such lines, but one meets occasionally spots of true aridity in their midst. Such localities present the anomalous spectacle of permanently deforested areas supporting species of grasses and other herbaceous plants peculiar to the arid plains at subalpine altitudes, and in regions where the situation seemingly should insure an abundance of precipitation. Excellent examples of these phases are seen in the Bitter Root forest reserve in Idaho. This region lies within an area of sufficiently heavy precipitation to be generally classed as humid above the 5,000-feet level; but arid and subhumid conditions have extended up the Clearwater and Salmon river valleys, in places reaching the main range, and overleaping this barrier have joined the arid regions of the interior Rocky mountain basins. The subhumid and semi-arid conditions have spread upward from the valley bottoms along the mountain slopes to elevations of 6,000 feet to 7,000 feet, carrying their peculiar shrubs and trees with them. We cannot account for the permanency of these arid and semi-arid extensions, except by adopting the proposition that a progressive diminution of the annual precipitation is now an established and general climatic feature in this region.

Coexistent with the advance of drier climatic conditions into the humid areas, we find, as already noted, many of the trees and shrubs of the semi-arid and subhumid tracts, while the entire forest has been profoundly disturbed in its equilibrium. Among the shrubs of the arid and semi-arid regions which have thus penetrated into the humid areas may be mentioned *Cercocarpus ledifolius*, *Kunzia tridentata*, *Artemisia tridentata*, *Artemisia arbuscula*, and one or two species of Forsellesia. These shrubs abound on the arid regions of the plains, to which they properly belong. They are found following the subhumid areas into the humid ones in the Bitter Roots, in the Rocky mountains, and in the Cascades. Their presence and distribution here proves un-

mistakably progressive semi-aridity into the subhumid tracts, subhumid extensions into the humid areas.

In the semi-arid belt we noted the occurrence of detached aggregates and scattered individuals of its forest growth separated from the main body by deforested lanes and wide stretches. They were taken to represent the effects of a gradual invasion of the adjacent arid conditions, creating a sort of fringe or frayed edge of timber growth along the edge of the forest. If our ideas of progressively drier conditions extending throughout the different belts of humidity are in accordance with facts, we have a right to expect analogous phenomena in the humid and subhumid areas. That is exactly what we find, but they differ from those which exist in the arid and semi-arid region in this way: that the edge of the advancing semi-aridity into the subhumid tracts and the front of the subhumidity where it penetrates into the humid areas are not typically marked by deforested openings. Instead, they present detached groups of the species, which belong to the upper and more humid tracts of each of the zones, entirely surrounded by heavy bodies of the kinds which belong to the lower zones and which are capable of withstanding greater dryness.

In examining the phenomena of forest growth in the humid areas, as changed or in process of modification by the shifting climatic conditions, we can find no localities within these regions that present the various phases so clearly and indisputably as does the west slope of the Bitter Root mountains. This area is truly a debatable ground. Its forest growth is subject to great and extensive stress—on the east from the arid conditions of the Rocky Mountain regions, on the west from those which prevail on the treeless plains of the Columbia River plateau. It is seamed, furrowed, and crossed in various places by extensions from those two great tracts. At the same time it contains very large areas of extremely humid slopes, where the drying effects of the changing climate are as yet scarcely felt, if at all. These conditions provide numerous transition grounds for the study of the forest modifications.

Beginning with the group of summit trees, as they might be called, we have three species which are in the Pacific northwest true timber-line trees. Nowhere, however, in the Bitter Roots do these species form a timber-line zone, for no peak in the range is high enough to reach it. As summits exist 10,150 feet in height above sea-level, it follows that the absolute timber-line

is here phenomenally high—a significant fact in connection with the wide extensions of subhumid and semi-arid conditions into the interior of this range, and a possible consequent rise of the mean annual temperature. The absence of a timber-line even at the highest peaks was noted and commented upon by the various parties engaged in the first surveys for a northern transcontinental railroad route, but was generally ascribed to the effects produced by a current of warm air supposed to move eastward from the plains of the Columbia in this latitude.

None of the three species contained in the summit group of trees possesses any marked power of adaptation. The Lyall larch is wholly deficient in this respect. The white-bark pine ranks slightly higher, and the mountain hemlock somewhat above the latter, as shown by its occurrence within undoubted subhumid conditions in some localities, as in the middle portion of the Deschutes basin in Oregon. In the Bitter Roots we find the Lyall larch along the high crests of the main range from a point just north of Nez Perce pass to an as yet undetermined northern point. However, it does not go very far beyond the ridges which bound the north fork of Clearwater basin. It is found on both the east and west slopes of the range, extending three to four miles away from the crest on either side. The western spurs of the range present one or two outlying small groves of the species on the divide between the Lochsa and Selway forks. Its habitats in the Bitter Root range are absolutely cut off from all connection with others elsewhere by gaps of low altitudes a hundred miles or more in width, which now cannot possibly be spanned by the species. In these regions this larch is clearly approaching extinction. Its cone and seed production are extremely scanty. Its growth is excessively slow. Most of the individuals which make up the stands are far advanced in age. Seedlings or saplings are rare and scattered. No farther back than three centuries there must have been abundant seed production, as a majority of the trees are approximately of this age. Three centuries hence the stands, if existing at all, will show great diversity of age, unless the cone-bearing periods run in cycles, long intervals of barrenness being followed by periods of fertility. Whatever rotation may exist in this respect (and that some does occur admits of no doubt) it operates only within narrow limits of time, producing what are called "off years," and does not impress itself very strongly upon the stand of the species as a whole.

Passing to the white-bark pine, we find it extending over all the ridges and spurs of the Bitter Roots having elevations above 6,000 feet. On the north the range of the tree is intercepted by the valleys of the Clark fork and the Bitter Root river. On the south it follows the crest of the ridges into the Rocky mountains. The species is lacking in vigor and is not maintaining its former stands. It is a conspicuously shy cone producer throughout all this region. The staminate blossoms or aments are borne in the greatest profusion, but the pistillate are very rare. In consequence, but few cones are seen, and the seedlings, while not wholly absent, are very sparse and scattered.

The mountain hemlock occurs on the ridges above 5,500 feet elevation throughout the central areas of the Bitter Root system. It is cut off on all sides from connection with the species elsewhere by wide stretches where it is wholly lacking. In the northern portion of its range it is an abundant cone and seed producer, and is maintaining the average densities of its stands. Its southern boundary in this region lies along the crest which separates the north and middle forks of Clearwater. All along this southern edge it abuts upon the subhumid tracts which spread upward along the slopes of the low-lying valley of the middle or Lochsa fork of the Clearwater. A low ratio of cone and seed-bearing capacity marks the southern edge of its range, and its seedlings are far from sufficient in number to keep the stands at their maximum density. Throughout the entire Bitter Root region the declining vitality of the species is indicated by its small cones, which do not average one-half of the normal size for the more vigorous type of the species. The habit of the three summit species is inimical to survival under very great stress of subhumidity. Their place of growth is invariably on drained slopes. If through adaptation they should acquire the power to grow in wet or saturated soil, they would stand a far better chance of survival, but no evidence exists of any such modifications.

Below the summit group of trees are the species of the second group. Among these the western larch possesses the greatest power of adaptation, next the mountain white pine, then the Pacific arbor-vitæ, and last the western hemlock. The western larch is able to endure subhumid conditions which, in places, almost border on semi-aridity. Of the trees distinctly belonging to the humid areas, it is the last to retreat before the advancing line of climatic siccation. All these species are at home in wet

or swampy localities, and are therefore better fitted for a lengthy resistance than would otherwise be the case. Their northward range extends indefinitely to the limits where the mean temperature becomes too low for their growth. Their southward boundary in the Bitter Root region lies a few miles north of a line drawn east and west through the crest of the divide which separates the Salmon river from the Clearwater drainage. Northeastward they cross the Bitter Roots into the Rocky Mountain ranges, while in the northwest they extend through the mountains between the Fraser river and the Columbia into the Cascades. Owing to the circumstance already mentioned—that the species can exist in swampy ground—they hold their own against the subhumid encroachments everywhere but along their southern edge. Their retreat is here marked, exactly as in the case of other species, by deficient cone and seed production and by the occurrence of detached bodies of the species along the line of retreat.

The third group of the humid series of trees contains species whose adaptability to varying altitude and moisture conditions is of the highest. This is owing to their capacity for enduring very diverse habitats. They are equally at home on dry, well-drained slopes, or in wet places, where their roots are continually immersed in circulating water. Among the three, the lodgepole pine has the greatest endurance, and all appearances indicate that it is the species which eventually will supplant the other species in the humid regions.

The Alpine fir ranges throughout the entire extent of the Bitter Root mountains, and extends indefinitely north and south, east and west, along the crests of connecting ridges. It is a fair producer of cones and seeds, and is maintaining its stands in most localities. Its susceptibility to adverse subhumid conditions is found in the occurrence of large deforested tracts occupied by the tree within comparatively recent times, but which now show no evidence of a return to forest cover. Such tracts are frequent everywhere throughout its range in these regions. Generally they front on some broad valley, along whose slopes the subhumid or semi-arid changes are advancing into the mountains.

The Engelmann spruce and the lodgepole pine have a universal range throughout the mountains in this region. Both have developed forms to meet drier conditions. Engelmann spruce never reaches its greatest development except in swampy localities, where it grows to be a large, well-formed tree. On dry

ridges it exists as a small, knotty, branchy, undersized tree. The lodgepole pine follows the same general rule. The reproduction of these two species is excellent, and they are constantly occupying new ground to the exclusion of the other species.

The forest fires which ravage the mountains show how closely balanced are the majority of the humid species and how slim a hold they possess on existence along the front line of the spreading subhumidity. It is a fact patent to every one who studies the after-effect of a forest fire in this region that the increased evaporation from the denuded surfaces causes intense soil aridity. This condition is not alike in all places. Some localities, by reason of local topography or exposure, suffer more severely than others. There are thus on south-facing hillsides, near the larger valleys, numerous places where centuries ago the subalpine forest was destroyed by fire, and arid conditions set in to the extent of absolutely preventing reforestation to this day; but in the majority of cases the first burning of the forest destroys only the more tender species and favors the growth of those which possess greater power of adaptability. This in the humid areas means a preponderance of the lodgepole pine, because of its wide limit of tolerance to different climatic conditions. Fires in the humid growths hardly ever destroy the forest completely over any very large area. Small patches are left untouched, though surrounded by wide lanes of burned forest. The growth of lodgepole pine which comes in after the fires, because better fitted than any other species to endure soil aridity, follows the denuded areas and often covers them with dense stands. In so doing it cuts off these slices of unburned forest from all chance of regaining their former connection with the main body of their own type of growth, and gives rise to conditions which are somewhat analogous to those in the semi-arid belts, where deforested areas, supporting types of vegetation peculiar to arid regions, separate the outlying groves of forest.

It is not alone in the region of the Columbia river watershed that the increasing climatic aridity is modifying or disturbing the forest types and their ancient balance. The same phenomena are repeated in California, and are doubtless general throughout the Rocky mountains and the areas collectively termed "The Pacific Coast." A conspicuous example occurs in southern California, in the behavior of the big cone fir, *Pseudotsuga macrocarpa*, and the redwood, *Sequoia sempervirens*. The big cone fir is a common species on the slopes of the mountain ranges in south-

ern California. On the west slopes of the San Bernardino and San Jacinto ranges, its main body of growth is above the 4,000-feet contour line. Below this the tree thins out rapidly, and at elevations of 3,000 feet practically ceases. In the San Gabriel mountains it begins to grow at elevations of 1,000 feet above sea-level; at 3,000 feet it forms very numerous groves in the midst of the chaparral. Now, there are the clearest evidences that not very far back in time a nearly uniform forest of this species covered many of the slopes of the San Gabriel mountains between the 2,000-feet and 3,000 feet contour levels. The numerous single trees and old stumps in the chaparral are the remnants of this growth. Moreover, when the big cone fir is burned out on the slopes below the 4,000-feet level, neither it nor any other species of conifers reforest the denuded areas, showing that conditions exist which are inimical to forest growth. In the San Bernardino and San Jacinto ranges the lower edge of the big cone fir forest is tolerably compact and well defined. The outlying patches on the slopes that one sees so frequently in the San Gabriel are lacking. The extensions from the main body of growth are along the streams and gorges where abundant moisture exists. The San Bernardino and San Jacinto mountains are farther from the ocean than the San Gabriel; hence for same elevations they do not receive so heavy a precipitation, and have in consequence a higher limit for the lower edge of the range of the big cone fir. The San Gabriel mountains, being nearer the ocean, receive a greater precipitation; hence have an ulterior limit for the inferior edge of the big cone fir at a considerably lower elevation than the other two ranges; but the lack of reforestation on areas where the growth is destroyed and the many detached patches below the main body of growth prove that the species is retreating toward regions of greater humidity. As the process is aided and accelerated by forest fires of modern date, another generation will not pass before the lower limit for the growth of the tree in the San Gabriel mountains will be at quite as high altitude as it is in the San Bernardino and San Jacinto ranges. In comparison with the allied northern *Pseudotsuga mucronata*, or red fir, the species is more definite in cone and seed production.

The redwood is a tree of extreme susceptibility to temperature and humidity conditions, and apparently possesses a very low ratio of adaptability. It ranges along the California coast from Los Angeles county to the northern boundary of the state and across

into Oregon. At its extreme southern end it is represented by small scattered groups of trees—a few hundred individuals only are reported—and a long gap intervenes before its appearance farther north. The heaviest stands of the species are found in Mendocino and Humboldt counties, in California. It thins out toward the Oregon line and finally disappears a few miles north of the boundary. The northward extension of the species is evidently limited by a mean annual temperature lower than its ultimate point of endurance. Southern extensions are impossible, owing to an insufficiency of rainfall in that section of California, and its spread into the interior, away from the proximity of the ocean, is precluded by adverse conditions of both temperature and humidity. The reproduction of the species is said to be very low. Cut-over areas show no evidences of reforestation with the same species. Thus hemmed in by inimical climatic conditions and unable to maintain its stands, its extinction seems assured at no very remote period.

SUMMARY

The salient points brought out by a study of the forest conditions in these regions, so far as they relate to the effects of climatic aridity, can be stated concisely as follows:

The arid, non-forested plains regions of eastern Oregon yield silicified remains of arborescent vegetation identical or nearly so with existing species on adjacent areas, proving the presence of forest growth on these timberless lands at no very remote period.

The forests on the semi-arid tracts, although consisting of species capable of enduring dry climatic conditions, show everywhere a persistent and gradual dwindling in extent and density. Their stands, consisting mostly of old trees, show a conspicuous deficiency in seed production, an enormous percentage of the ovules aborting, and a notable scarcity of seedlings. When, from any cause, a tract of the old stands is deforested, reforestation does not occur, as a rule; this results in the formation of detached groves and individuals whose reproductive powers become even more limited and weakened and the extinction of which is merely a matter depending on the age limit of the individual trees.

In the subhumid forest there is a slow and apparently ineffectual adaptative evolution of smaller forms of the various species to replace the larger ones, which require more moisture for their growth. There is also a conspicuous shortage of cone

and seed production in the group of trees which form the upper subhumid types, and a pushing of the lower subhumid types which grow in drier atmospheric and soil conditions into the areas of the upper types, and frequently a complete and permanent replacement of the upper subhumid types with those belonging to the lower groups when such upper types have been destroyed by fire or other means.

In the humid forest are found the same phenomena as noted for the subhumid tracts, with areas in the upper humid belts, where certain species occupy tracts separated by long distances (sometimes a hundred miles or more) from the next appearance of the species elsewhere. These intervals, which break the continuity of the range of such species, are held to indicate more humid conditions in the part favoring extensions across these gaps, which are now precluded and cut off by adverse climatic changes in the direction of aridity.

PROFESSOR O. C. MARSH

Othniel Charles Marsh, LL.D., Ph.D., Professor of Paleontology in Yale University, Vertebrate Paleontologist of the U. S. Geological Survey, and a member of the National Geographic Society, died in New Haven, Connecticut, March 18, 1899. His death removes an eminent contributor to American science.

Born in Lockport, New York, October 29, 1831, Marsh grew up an athlete and sportsman, rather than student, until his observations on nature directed his attention to the natural sciences. In 1852 he went to the Phillips-Exeter academy at Andover, whence he graduated as the valedictorian of his class. In 1856 he matriculated at Yale, graduating with honors in 1860. Subsequently he retained almost constant connection with his alma mater, to whose prestige he contributed much, the longest interruption occurring in the early sixties when he was engaged in special work in European universities. In 1866 he was made Professor of Paleontology, a position retained until his death. The nephew and heir of George Peabody, he was the possessor of means enabling him to exercise his strong individuality freely in the prosecution of scientific researches. His best-known work was that of explorer in the western territories and collector of vertebrate fossils, by which the museum of Yale and U. S. National Museum were enriched; yet his most enduring monument takes the form of original contributions to vertebrate paleon-

tology. His researches were conducted with remarkable vigor, notable acumen, and exceptionally clear recognition of the principles of biology. To the general surveyor of the field of organic life, past and present, several of Professor Marsh's contributions seem to be of the first magnitude: The modern method of seeking and quarrying for complete skeletons to be used as material for study, in lieu of resting content with fragments, was largely due to his broad views and pertinacious industry, and his liberal expenditure of private means; partly by reason of this method, he was able to classify extinct forms, and trace their relations to living organisms in a superior manner; while his improved methods in field and laboratory enabled him to give unprecedented vitality and living interest to the animals of ages past and the life history of the earth primeval. Among his special contributions, the tracing of the phylogeny of the horse attracted world-wide attention, while his development of the principle of cephalization is of exceeding service to biologists and anthropologists, as well as to specialists in his own domain. During the last decade he turned attention to geology, and his researches in the Atlantic Coastal plain have received much attention and yielded results of permanent value.

Professor Marsh's scientific work brought recognition from various institutions. He held honorary connection with several European academies of science, and was the recipient of the Cuvier prize of the Institute of France and of the Bigsby medal of the Geological Society of London; he was President of the American Association for the Advancement of Science in 1878, and President of the National Academy of Sciences for twelve years, 1883–1895. A bachelor and the last of his line, he bequeathed practically the whole of his considerable property to Yale University. W J M.

THE AREA OF THE PHILIPPINES

In a recent communication to the Geographical Society of the Pacific, of which he is President, Prof. George Davidson writes as follows:

In several government documents the statement is made that the area of the Philippine islands is something over 114,000 square miles. In the latest one just received it is given as 114,326. This error has doubtless arisen from a hurried examination of the Spanish documents. We find in the "Guia Oficial de las Islas Filipinas, para 1898; Publicada por la Secretaria del Gobierno General; Manila, 1898," the statement that the

archipelago comprises an area of 355,000 square kilometers, without including the Jolo (Sulu) group. It then specifies about thirty of the principal islands, and their areas aggregate 298,485 square kilometers. That, of course, leaves a multitude of the smaller islands not specified in the guide, but covered by the larger area. As the number of square kilometers multiplied by .386052 will give the number of square miles, the area of the islands specified amounts to 115,238 square miles, and the area of all the islands, less the Jolo group, amounts to 137,057 square miles. Further, the statement is generally made that the Archipelago of the Philippines contains from 1,000 to 2,000 islands, and the "Guia Oficial" says the number is more than 1,200. But in examining the "Derrotero del Archipielago Filipino, Madrid, 1879"—that is, the Coast Pilot of the Philippines, covering more than 1,200 pages—we find that the Islas, Islitas, Isletas, Islotes, Islotillas, and Farallones therein described amount to 583. Of course, this does not include reefs, rocks, or hidden dangers. I submit that these figures of the areas and of the number of islands and islets be accepted until replaced by government surveys.

THE RECENT ASCENT OF ITAMBÉ

In his letter referring to the ascent of Itambé, Lieutenant Shipton states (this magazine, November, 1898, p. 476) that "we are supposed to have been the first men ever on the summit of this peak." Itambé was ascended and measured by Spix and Martius in 1818. Those authors say of it: "The peak of Itambé, the highest one ascended and measured by us in all our travels through Brazil, has an elevation of 5,590 Parisian feet."* This measurement was made with a mercurial barometer, and, so far as I know, it has never been repeated.

The fact that Itambé has not been ascended is due to its being in a thinly populated, untraveled country, rather than to any particular difficulty in getting up the peak itself. It dominates almost the entire diamond district of Minas, and in my own travels through that region I was constantly reminded of what Dr Santos says—that this peak served the old gold and diamond hunters instead of a compass, for they never got lost so long as it was in sight. "It was a granite light-house to travelers—the center of a circle, seventy leagues in diameter, in which they could revolve without fear of getting lost."†

J. C. BRANNER.

Stanford University.

* Reise in Brasilien von Dr J. B. von Spix und Dr C. F. P. von Martius, ii, 456, München, 1828; also Beiträge zur Gebirgskunde Brasiliens von W. L. von Eschwege, 334, Berlin, 1832.

† Memorias do Districto Diamantino, por J. F. dos Santos, p. 8, Rio de Janeiro, 1868.

MISCELLANEA

The total imports of the Samoan islands amounted in 1895 to $418,840 and the total exports to $256,758. The share of the United States was but $60,624 in the imports and $33,050 in the exports.

The government of Haiti has imposed a surplus tax of 25 per cent on all importations, in effect from March 14, 1899. The proceeds are to be applied to the withdrawal of the paper money now in circulation.

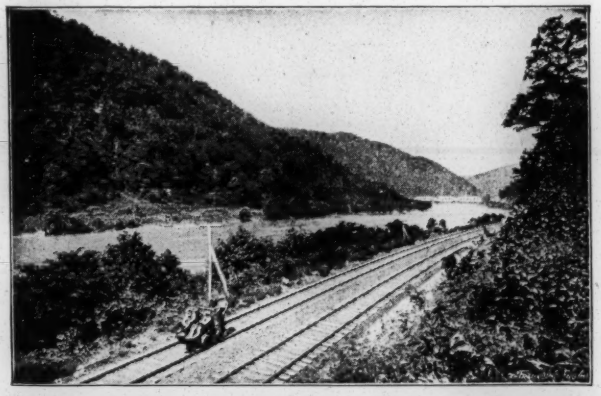
The Austrian Lloyds have recently established a direct service between Trieste and Calcutta. Austria is becoming an important factor in the rivalry of the greater European powers for the markets of the far East.

The Simplon tunnel, when completed, will be 21,580 yards long. It will contain only a single track, but a second tunnel is to be constructed parallel to it, at a distance of 19 yards. The northern entrance to the tunnel is about a mile and a half from the station at Brieg, at an elevation of 2,254 feet. The exit on the Italian side will be 800 yards from Isella.

To prevent the extinction of india-rubber trees in the Congo Free State, the government has decreed that for every ton of rubber yielded annually there must be planted not less than 150 trees. The law which prohibits gathering rubber except through incisions in the bark is to be more strictly enforced, and violations will be punished by a fine up to $2,000, or by imprisonment.

An English syndicate has begun the construction of additional quays and magazines at Genoa. In 1897, 5,000,000 tons of merchandise passed through the warehouses of this port, and it is calculated that with the completion of the Simplon tunnel and the consequent improvement in railway communication, the annual tonnage will rise as high as 10,000,000. Genoa will then be the most important port of the Mediterranean.

In a recent report to the Department of State, Mr Thomas E. Moore, U. S. Commercial Agent at Weimar, gives some valuable statistics concerning the balance of trade and the increase of population in Germany. The rapidly increasing population has caused a corresponding increase in the imports of provisions and raw materials, the home products not being sufficient to meet home demands. The population of the German Customs Union has risen from 50,960,000 in 1893 to 54,530,000 on July 1, 1898, an increase of 3,570,000, or 7 per cent within five years. The value of imports has increased by 29.5 per cent, and that of exports by 27 per cent. With the increase of population has also come a very apparent expansion of the productive capacity of the manufacturing industries. This is especially well shown by the steady output of steam-engines. The total horse-power of the steam-engines built in 1888 was 1,683,000, while in 1898 the total was 3,422,000. The most significant figures, however, are those of the manufacture of stationary engines during the last three years. In 1896 the total horse-power was 2,534,000; in 1897, 2,714,000; in 1898, 2,947,000. Agriculture does not show a corresponding development, as the limits of the grain-growing area can be extended but slowly.



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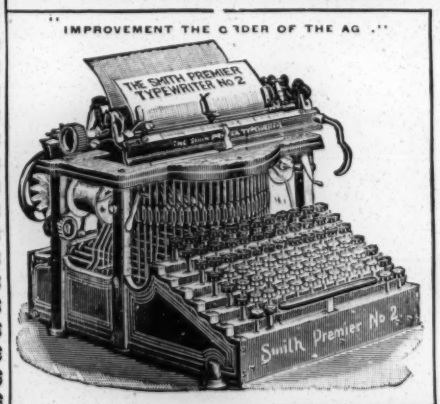

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